

Technical Memorandum

Date: June 3, 2022
To: Ohio EPA
From: David L. Elam, Jr.
Project: 483262.0000
Subject: Material Balance Calculations for Ammonia, Emerald Bioenergy Lagoon L7,
Cardington, OH

TRC Environmental Corporation (TRC) was asked to calculate potential ammonia (NH₃) atmospheric emissions from the lagoon at the Emerald Bioenergy Facility (Emerald) using a material balance approach. This brief memo provides an overview of the process, the material balance approach, and the results of the material balance calculations. This approach assumes that changes in the total ammoniacal nitrogen (TAN) inventory are due to the volatilization of NH₃ from the lagoon surface.

Process Description: The Emerald facility receive hog manure and food wastes and mixes them in proportions that vary based on digester chemistry needs. The mixed slurry is then transferred to an adjacent anaerobic digester for the production of biogas which is burned on site to generate electricity. Digestate is discharged from the digester to a lagoon (L7). The digestate is subsequently removed periodically for land application to amend agricultural land. Over time, the discharge volume from the digester is roughly equal to the volume of slurry that is supplied to it. A process flow sketch is provided in Attachment A.

Emerald collects process data including food waste dosing in gallons, hog waste dosing in tons (which is converted to gallons using a conversion factor of 7.8 pounds per gallon), and digestate removed for land application in gallons. Emerald also collects a variety of analytical data to manage digester chemistry.

A four-week sampling program was conducted at Emerald to gather data for the material balance calculations. Samples were collected on May 2, 2022, May 9, 2022, May 16, 2022, and May 23, 2022. For each sampling event, samples were collected from both the digester recirculation loop and the lagoon. Samples from the recirculation loop are representative of the material that is discharged from the digester to the lagoon. Lagoon samples were collected distant from the pipe from the digester that discharges into the lagoon at a depth of approximately 14 feet. The lagoon samples are representative of the digestate that is removed for land application.

The samples were analyzed for a variety of parameters. Only the TAN data are relevant for the ammonia balance calculations.

Mass Balance Approach: TRC's approach to the mass balance calculations is outlined below:

1. Food waste and hog manure volumes supplied to the digester were recorded daily for both sampling programs.
2. For the purposes of these mass balance calculations, the digester feed volume was set equal to the volume removed for land application. In practice, digestate accumulates in the lagoon and is removed periodically.
3. Grab samples were collected from the recirculation loop and lagoon on the indicated sample dates and analyzed for TAN. Material balance calculations were performed for TAN. The lab reported TAN concentrations in percent nitrogen (N), which were converted to milligrams per liter (mg/l) by multiplying the reported value by 10,000 (1% = 10,000 ppm = 10,000 mg/l). No adjustments were made for specific gravity because the specific gravity values were very close to 1 gram per milliliter (g/ml).
4. The total dosing volume in gallons was converted to liters using 3.785 liters per gallons.
5. The daily masses of TAN were calculated by multiplying the concentration in mg/liters by the dosing volume in liters for the sample period interval. The resulting value in mg was converted to pounds (lb) using conversion factors of 1,000 mg/g and 454 g/lb. The daily mass was calculated by dividing the total by the number of days in the sample period interval.
6. Potential emissions, as N, were calculated by subtracting the per day total mass of TAN calculated for the lagoon from the per day total mass of TAN calculated for the recirculation loop. Differences are reported to the nearest tenth while daily values have been reported to the nearest whole number. Calculations were performed to two decimal places, which sometimes results in a rounding error. For example,
7. Potential emissions, as NH_3 , were calculated by multiplying emissions as N by the ratio of the molecular weight of NH_3 (17 grams/mole) to that of nitrogen (14 grams/mole), which is 1.214.
8. An example material balance calculation is provided on page 3.
9. Laboratory reports are provided in Attachment B.

Results: Digester dosing data and mass balance calculation results are presented in Tables 1 and 2 on pages 4 and 5. Shaded cells represent sample collection dates.

Example Material Balance Calculations

$$\text{Period Total Waste Dosing (Gallons)} = \Sigma [\text{May 1 to May 23, 2022}] = 62,512 \text{ Gallons}$$

$$\text{Period Total Waste Dosing (Liters)} = 62,512 \text{ Total Waste Dosing (Gallons)} \times 3.785 \frac{\text{Liters}}{\text{Gallon}}$$

$$= 236,607 \text{ Liters Waste}$$

$$\text{Recirculation Loop (mg N/Liter)} = 0.2368\% \times \frac{1,000,000 \text{ ppm}}{100\%} = 2368 \text{ ppm} \times \frac{1 \text{ mg/Liter}}{1 \text{ ppm}} = 2368 \text{ mg/Liter}$$

$$\text{lb of N} = 2368 \frac{\text{mg}}{\text{Liter}} \times 236,607 \text{ Liters} \times \frac{1}{1000 \frac{\text{mg}}{\text{g}} \times 454 \text{ g/lb}} = 1234 \text{ lb of N}$$

$$\text{Average lb of N per day} = \frac{1234 \text{ lb}}{23 \text{ days}} = 54 \frac{\text{lb}}{\text{day}} \text{ N}$$

Same Equations used for Lagoon

$$\text{Potential Emissions per Day as N} = 54 \frac{\text{lb}}{\text{day}} \text{ Recirculation} - 33 \frac{\text{lb}}{\text{day}} \text{ Lagoon} = 21.1 \frac{\text{lb}}{\text{day}} \text{ as N}$$

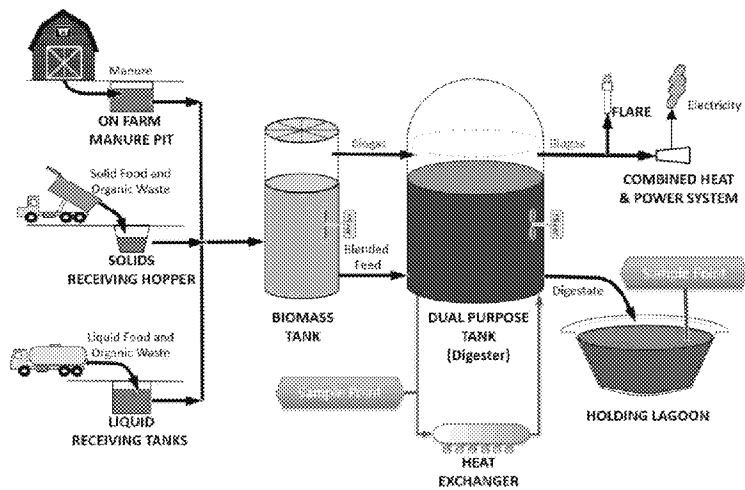
$$\text{Potential Emissions per Day as NH}_3 = 21.1 \frac{\text{lb}}{\text{day}} \text{ as N} \times \frac{17 \frac{\text{g}}{\text{mole}} \text{ NH}_3}{14 \frac{\text{g}}{\text{mole}} \text{ N}} = 25.6 \frac{\text{lb}}{\text{day}} \text{ as NH}_3$$

Table 1. Food Waste and Hog Manure Dosing Volumes, May 1, 2022 - May 23, 2022, Emerald			
Date	Food Waste Dosing, Gallons	Hog Waste Dosing, Gallons	Total Dosing, gallons
5/1/2022	5,137	0	5,137
5/2/2022	4,859	0	4,859
5/3/2022	3,469	0	3,469
5/4/2022	5,111	8,053	13,164
5/5/2022	7,584	0	7,584
5/6/2022	7,734	0	7,734
5/7/2022	0	0	0
5/8/2022	0	0	0
5/9/2022	4,317	0	4,317
5/10/2022	2,476	0	2,476
5/11/2022	0	0	0
5/12/2022	0	0	0
5/13/2022	0	0	0
5/14/2022	0	0	0
5/15/2022	0	0	0
5/16/2022	0	0	0
5/17/2022	4,602	0	4,602
5/18/2022	1,103	0	1,103
5/19/2022	1,012	0	1,012
5/20/2022	1,087	0	1,087
5/21/2022	1,943	0	1,943
5/22/2022	1,943	0	1,943
5/23/2022	2,082	0	2,082
Period Total, gallons	54,459	8,053	62,512
Period Total, liters	206,127	30,479	236,607

Table 2. TAN Mass Balance Calculations, May 1, 2022 – May 26, 2022, 23 days, Emerald			
	TAN, mg/L		TAN Pounds
Recirculation Loop			
May 2, 2022	2,120	pH == 7.8	
May 9, 2022	2,480	pH = 7.6	
May 16, 2022	2,430	pH = 8.2	
May 23, 2022	2,440	pH = 7.9	
Average	2,368	Period Total, pounds	1,234
		Per Day Total, pounds	54
Lagoon			
May 2, 2022	1,400	pH = 7.2	
May 9, 2022	1,350	pH = 7.2	
May 16, 2022	1,560	pH = 7.0	
May 23, 2022	1,440	pH = 7.4	
Average	1,683	Period Total, pounds	749
		Per Day Total, pounds	33
	Difference	Per Day, pounds	21.1
	Potential Emissions, lbs, as N	Per Day, pounds	21.1
	Potential Emissions, lbs, as NH₃	Per Day, pounds	25.6

Attachment A: Process Flow Diagram

The following process flow diagram, representative of operations at Emerald, was prepared by Azura Associates.



Attachment B: Laboratory Reports

Sample collection dates are missing from some lab reports. Azura Associates has communicated with Emerald management and confirmed that the results for the dates presented in this report are correct.

BROOKSIDE LABORATORIES, INC.

** MANURE ANALYSIS REPORT **

Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/17/2022
Date Reported: 05/19/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number 3612
Description EMERALD-DUAL
TANK RECIRC LOOP
Samples Collected 5/2/22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		98.64	8133.5
Mineral Matter	50.00	0.68	56.07
Lost By Ign (Org M+)	50.00	0.68	56.07
Total Nitrogen	16.76	0.228	18.80
Ammonium-N (NH ₄ -N)	15.59	0.212	17.48
Nitrate-N (NO ₃ -N)		< 0.010	
Organic-N	1.17	0.016	1.32
Phosphorus (P)	2.43	0.033	2.72
Phos. as (P205)	5.59	0.076	6.27
Potassium (K)	7.13	0.097	8.00
Potassium as (K20)	8.60	0.117	9.65
pH		7.79	
Specific Gravity (g/mL)		0.99	

Reviewed by



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PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/17/2022
Date Reported: 05/19/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number 3613
Description EMERALD-LAGOON

Samples Collected 5/2/22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		96.27	7893.1
Mineral Matter	39.95	1.49	122.16
Lost By Ign (Org M+)	60.05	2.24	183.66
Total Nitrogen	5.52	0.206	16.89
Ammonium-N (NH ₄ -N)	3.75	0.140	11.48
Nitrate-N (NO ₃ -N)		< 0.010	
Organic-N	1.77	0.066	5.41
Phosphorus (P)	1.80	0.067	5.49
Phos. as (P2O5)	4.13	0.154	12.63
Potassium (K)	1.23	0.046	3.77
Potassium as (K2O)	1.47	0.055	4.51
pH		7.21	
Specific Gravity (g/mL)		0.98	

Reviewed by



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** MANURE ANALYSIS REPORT **

Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/11/2022
Date Reported: 05/13/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number	3307
Description	EMD-DUAL PURPOSE RECIRC LOOP 9-MAY-22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		98.21	623.69
Mineral Matter	44.13	0.79	5.02
Lost By Ign (Org M+)	55.87	1.00	6.35
Total Nitrogen	13.91	0.249	1.58
Ammonium-N (NH4-N)	13.85	0.248	1.57
Nitrate-N (NO3-N)		< 0.010	
Organic-N	0.06	0.001	0.01
Phosphorus (P)	3.24	0.058	0.37
Phos. as (P2O5)	7.43	0.133	0.84
Potassium (K)	5.25	0.094	0.60
Potassium as (K2O)	6.31	0.113	0.72
pH		7.61	

Reviewed by



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Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/11/2022
Date Reported: 05/13/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number 3308
Description EMD-LAGOON
9-MAY-22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		94.69	571.31
Mineral Matter	30.32	1.61	9.71
Lost By Ign (Org M+)	69.68	3.70	22.32
Total Nitrogen	3.99	0.212	1.28
Ammonium-N (NH4-N)	2.54	0.135	0.81
Nitrate-N (NO3-N)		< 0.010	
Organic-N	1.45	0.077	0.46
Phosphorus (P)	1.60	0.085	0.51
Phos. as (P2O5)	3.67	0.195	1.18
Potassium (K)	0.85	0.045	0.27
Potassium as (K2O)	1.02	0.054	0.33
pH		7.23	

Reviewed by



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PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/17/2022
Date Reported: 05/19/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number	3592
Description	EMD-DUAL PURPOSE RECIRC LOOP 16-MAY-22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		98.30	8216.2
Mineral Matter	50.00	0.85	71.05
Lost By Ign (Org M+)	50.00	0.85	71.05
Total Nitrogen	14.65	0.249	20.81
Ammonium-N (NH ₄ -N)	14.29	0.243	20.31
Nitrate-N (NO ₃ -N)		< 0.010	
Organic-N	0.36	0.006	0.50
Phosphorus (P)	3.35	0.057	4.76
Phos. as (P205)	7.71	0.131	10.95
Potassium (K)	5.59	0.095	7.94
Potassium as (K2O)	6.71	0.114	9.53
pH		8.18	
Specific Gravity (g/mL)		1.00	

Reviewed by



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** MANURE ANALYSIS REPORT **

Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/17/2022
Date Reported: 05/19/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number 3593
Description EMD-LAGOON

16-MAY-22

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		93.26	7622.2
Mineral Matter	28.49	1.92	156.92
Lost By Ign (Org M+)	71.51	4.82	393.94
Total Nitrogen	3.77	0.254	20.76
Ammonium-N (NH ₄ -N)	2.31	0.156	12.75
Nitrate-N (NO ₃ -N)		< 0.010	
Organic-N	1.46	0.098	8.01
Phosphorus (P)	1.45	0.098	8.01
Phos. as (P205)	3.34	0.225	18.39
Potassium (K)	0.79	0.053	4.33
Potassium as (K2O)	0.95	0.064	5.23
pH		6.98	
Specific Gravity (g/mL)		0.98	

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** MANURE ANALYSIS REPORT **

Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/24/2022
Date Reported: 05/26/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number	4023
Description	EMD-DUAL PURPOSE RECIRC LOOP

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		98.37	8163.0
Mineral Matter	47.85	0.78	64.73
Lost By Ign (Org M+)	52.15	0.85	70.54
Total Nitrogen	15.03	0.245	20.33
Ammonium-N (NH4-N)	14.97	0.244	20.25
Nitrate-N (NO3-N)		< 0.010	
Organic-N	0.06	0.001	0.08
Phosphorus (P)	2.70	0.044	3.65
Phos. as (P205)	6.20	0.101	8.38
Potassium (K)	5.83	0.095	7.88
Potassium as (K2O)	6.99	0.114	9.46
pH		7.94	

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BROOKSIDE LABORATORIES, INC.

** MANURE ANALYSIS REPORT **

Renergy, Inc.
PO Box 249
Delaware, OH 43015

File Number: 58251
Date Received: 05/24/2022
Date Reported: 05/26/2022

Submitted By: Brookside Consultants of Ohio, Inc.

Lab Number	4024
Description	EMD-LAGOON

	% Dry Basis	% Wet Basis	lbs/ 1000gal
Moisture		95.46	7726.3
Mineral Matter	36.12	1.64	132.74
Lost By Ign (Org M+)	63.88	2.90	234.72
Total Nitrogen	5.04	0.229	18.53
Ammonium-N (NH4-N)	3.17	0.144	11.66
Nitrate-N (NO3-N)		< 0.010	
Organic-N	1.87	0.085	6.88
Phosphorus (P)	1.76	0.080	6.48
Phos. as (P2O5)	4.03	0.183	14.81
Potassium (K)	1.12	0.051	4.13
Potassium as (K2O)	1.34	0.061	4.94
pH		7.39	

Reviewed by

